

## Evaluation of the alveolar antral artery position in the lateral sinus wall using cone-beam computed tomography

Evaluation of the alveolar antral artery position in the lateral sinus wall

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### Abstract

**Aim:** The aim of this study was to evaluate the prevalence and anatomic position of the alveolar antral artery (AAA) in different tooth regions of patients who underwent maxillary cone-beam computed tomography (CBCT) imaging.

**Materials and Methods:** CBCT images of 150 patients (59 males and 91 females) were included in the study. On the coronal images, localization of AAA relative to sinus lateral wall, the diameter of AAA and classification of AAA diameter were recorded for 1st premolar, 2nd premolar, 1st molar, and 2nd molar teeth levels separately.

**Results:** The prevalence of the detected arteries significantly increased antero-posteriorly from the 1st premolar to the 2nd molar ( $P < 0.05$ ). The mean diameter of the AAA was found to be  $0.91 \pm 0.33$  mm (range 0.25-2.90 mm) and the mean diameter of the AAA was significantly greater in males than in females ( $P = 0.001$ ). The AAA diameter increased antero-posteriorly from the 1st premolar to the 2nd molar. When evaluating the position of the arteries in the lateral wall of the sinus, the most frequent type of arteries was intraosseous (57.7%), followed by intrasinus (39.0%) and superficial (3.3%). It was observed that 95.24% of all superficial type of AAAs was in the 2nd molar region.

**Discussion:** AAA is an important structure and the clinician should be aware of location and course of the artery for surgical procedures. Careful evaluation of the AAA in maxillary sinus on CT images before surgery could reduce the possibility of excess bleeding, especially in molar areas.

### Keywords

Cone-beam Computed Tomography; Sinus Floor Augmentation; Blood Vessels; Intraoperative Complications

DOI: 10.4328/ACAM.20084 Received: 2019-12-06 Accepted: 2019-12-26 Published Online: 2019-12-30 Printed: 2020-07-01 Ann Clin Anal Med 2020;11(4):330-334

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## Introduction

Having the largest volume within the paranasal sinuses, the maxillary sinus is an important entity that is in close relation with the roots of premolar and molar teeth in the upper jaw. In terms of dentistry applications, maxillary sinus anatomy should be well known [1,2]. Especially during the maxillofacial surgical procedures, osteotomies are performed on the lateral wall of the maxillary sinus in surgical interventions such as the Caldwell-Luc, Le Fort I osteotomy, and more often, in sinus floor elevation with the lateral window approach. In these surgical procedures, there is a risk of hemorrhage originating from the antral artery [2]. Although the hemorrhage resulted from the antral artery does not pose a vital risk, it may hinder the vision during the operation, prolong the procedure and may severely affect the success of the operation [3]. The maxillary artery is one of the branches of the external carotid artery and is divided into 5 branches in the pterygopalatine fossa. The alveolar antral artery (AAA) is the anastomosis of the posterior superior alveolar artery (PSAA) and the inferior orbital artery which are the two branches of the maxillary artery. AAA is located along the side wall of the maxilla and supplies the periosteum, maxillary sinus and the sinus membrane [4,5]. In addition, AAA has an important role in wound healing and the blood supply of the graft material used in sinus floor elevation procedures [6]. The sufficient amount of bone surrounding the implants is a necessity after tooth loss in order to achieve long-term successful results [7]. Maxillary sinus floor elevation is a safe and successful method that can be used to regenerate the bone volume required for implant placement in the posterior maxilla [8]. The lateral window and the crestal approach are the two main techniques used to elevate the sinus floor. In cases with severely reduced residual alveolar bone, the lateral approach is more preferred and provides more predictable results [9]. Consideration and protection of the arteries that provide regional blood supply is important to prevent bone necrosis and to achieve good regional healing by providing ideal vascularization of the bone graft [10]. If the vascular structures in the region are damaged during the maxillary sinus floor elevation, serious bleeding may occur [11]. Hemorrhage can lead to complications such as perforation of the sinus membrane, decreased blood supply, bone necrosis, and graft displacement, decreased vision in the surgical field and prolongation of operation time [6]. Compared to standard computerized tomography, cone-beam computed tomography (CBCT) makes it possible to perform more accurate and reliable measurements with a lower radiation dose for dental and maxillofacial imaging [12]. Despite the use of panoramic radiographs and computed tomography [13] in the evaluation of AAA in the literature, there are very few studies using CBCT [10,14]. The aim of this study was to investigate the frequency of AAA in different tooth regions on CBCT images and to investigate the relationship between the artery and the lateral wall of the sinus.

## Material and Methods

This retrospective study was approved by Izmir Katip Çelebi University Non-Interventional Clinical Studies Institutional Review Board. The data of randomly selected 150 patients (59 males and 91 females) who had undergone CBCT imaging for various

diagnostic purposes between 2012 and 2018 at the Izmir Katip Çelebi University, Faculty of Dentistry were evaluated.

All CBCT images were obtained using NewTom 5G (QR, Verona, Italy) flat panel CBCT device. The images of the patients who were 20 years of age and older with the images of both maxillary sinuses with 15x12 field of view area and 0.2 mm voxel size were included in the study. Images were examined using the NNT (QR-NNT V9.1, Verona, Italy) program. Images with poor quality due to artifacts, patients with abnormalities in the sinus wall morphology due to trauma or pathological conditions, sinus surgery or grafting history and dental implants in the maxillary premolar-molar region were excluded from the study. Excluding 9 sinuses, a total of 291 maxillary sinuses were evaluated in 150 patients. On coronal images, the presence of AAA in different tooth regions on the right and left side of each patient was examined by a trained maxillofacial radiologist. In patients in whom the artery was detected, the artery diameter was measured using a digital caliper tool at locations corresponding to the crowns of maxillary 1st premolar, 2nd premolar, 1st molar, and 2nd molar. The diameter of the artery was divided into three categories: (1) diameter <1 mm, (2) diameter 1–2 mm, and (3) diameter ≥2 mm. In addition, the position of the artery in the lateral wall of the sinus was examined and classified as superficial (in the outer cortex of the lateral wall of the sinus), intraosseous (located inside the lateral wall), and intrasinus (located on the inner side of the lateral wall under the sinus membrane) (Figure 1, 2, and 3). CBCT images of fifty patients (30% of the images) were randomly selected and re-evaluated by the same examiner 2 weeks after the initial evaluation to determine intra-examiner reliability using the intraclass correlation coefficient (ICC).

## Statistical Analyses

The statistical analyses were performed using IBM SPSS Statistics 22.0 (IBM Corp., Armonk, New York, USA) statistical package program. The presence and frequency of AAA in relation to the tooth regions was evaluated by the Chi-Square test. The frequency of AAA types according to the tooth regions was evaluated by the Chi-Square test. The conformity of parameters to a normal distribution was assessed by the Kolmogorov-Smirnov test. An independent sample t-test was used to compare the gender differences of AAA mean diameters. The one-way ANOVA was used to evaluate the regional differences of AAA mean diameters.  $P < 0.05$  was considered statistically significant.

## Results

In our study, 291 maxillary sinuses were evaluated (115 sinuses of males [39.5%], 176 sinuses of females [60.5%]). The mean age of the patients was  $42.93 \pm 15.84$  years (male:  $40.49 \pm 16.01$ ; female:  $44.51 \pm 15.62$ ). The coefficients of reliability for all measurements were  $> 0.93$ . The results of the paired-sample t-test revealed no significant differences between the two sets of readings ( $P > 0.05$ ). The prevalence of the detected artery significantly increased antero-posteriorly from the 1st premolar to the 2nd molar ( $P < 0.05$ ) (Table 1). The mean diameter of the AAA was found to be  $0.91 \pm 0.33$  mm (range 0.25–2.90 mm). The mean diameter of the AAA was  $1.01 \pm 0.38$  mm in males and  $0.86 \pm 0.28$  mm in females. A significant difference was found in

the diameter of the AAA between males and females ( $P=0.001$ ). When diameters of the arteries were classified, 61.5% of the arteries were  $<1$  mm; 37.8% were 1–2 mm, and 0.8% were  $\geq 2$  mm. All arteries with  $\geq 2$  mm diameter were located in the 2nd molar region. Highly significant differences were found when AAA diameters were compared according to the tooth region ( $P < 0.001$ ). AAA diameter increased antero-posteriorly from the 1st premolar to the 1st molar. Although the AAA diameter was greater in the 2nd molar region than the 1st molar, the difference was not significant ( $P > 0.05$ ) (Table 2). When evaluating the position of the artery in the lateral wall of the sinus, the most frequent type of artery was intraosseous (57.7%), followed by intrasinusal (39.0%) and superficial (3.3%). While the intraosseous type was most common in the 2nd premolar region, the intrasinusal type was most common in the 1st molar region. The superficial type was most common in the 2nd molar region. The differences were statistically significant ( $P < 0.05$ ). Moreover, no superficial type was detected in the premolar region. It was also observed that 95.24% of all superficial type AAAs was in the 2nd molar region. This data suggests that the possibility of the lateral positioning of the artery increases as it goes toward the posterior region (Table 3).

**Table 1.** The prevalence of alveolar antral artery according to the tooth region.

	1st premolar n(%)	2nd premolar n(%)	1st molar n(%)	2nd molar n(%)	P
Presence n(%)	46 <sub>a</sub> (7.12%)	165 <sub>b</sub> (25.54%)	195 <sub>c</sub> (30.19%)	240 <sub>d</sub> (37.15%)	0.00*
Absence n(%)	245 <sub>a</sub> (47.30%)	126 <sub>b</sub> (24.32%)	96 <sub>c</sub> (18.53%)	51 <sub>d</sub> (9.85%)	
Total	291	291	291	291	

\*p < 0.01 (chi-square test).

**Table 3.** Position of the alveolar antral artery according to the tooth region.

Artery Position	1st premolar n(%)	2nd premolar n(%)	1st molar n(%)	2nd molar n(%)	P
Intraosseous	44 <sub>a</sub> (11.80%)	129 <sub>b</sub> (34.58%)	74 <sub>c</sub> (19.84%)	126 <sub>d</sub> (33.78%)	0.00*
Intrasinusal	2 <sub>a</sub> (0.79%)	36 <sub>b</sub> (14.29%)	120 <sub>c</sub> (47.62%)	94 <sub>d</sub> (37.30%)	
Superficial	0 <sub>a</sub> (0.00%)	0 <sub>a</sub> (0.00%)	1 <sub>a</sub> (4.76%)	20 <sub>b</sub> (95.24%)	
Total	46	165	195	240	

\*p < 0.01 (chi-square test).

**Table 2.** Comparison of the alveolar antral artery diameters (mm±SD) according to the tooth region.

Artery Diameter (mm±SD)				P					
P1 (n:46)	P2 (n:165)	M1 (n:195)	M2 (n:240)	P1-P2	P1-M1	P1-M2	P2-M1	P2-M2	M1-M2
0,67±0,22	0,84±0,31	0,96±0,26	0,98±0,37	0,001*	0,001*	0,001*	0,001*	0,001*	0,89

\*p < 0.05 (one-way ANOVA), P1= 1st premolar, P2= 2nd premolar, M1= 1st molar, M2= 2nd molar.

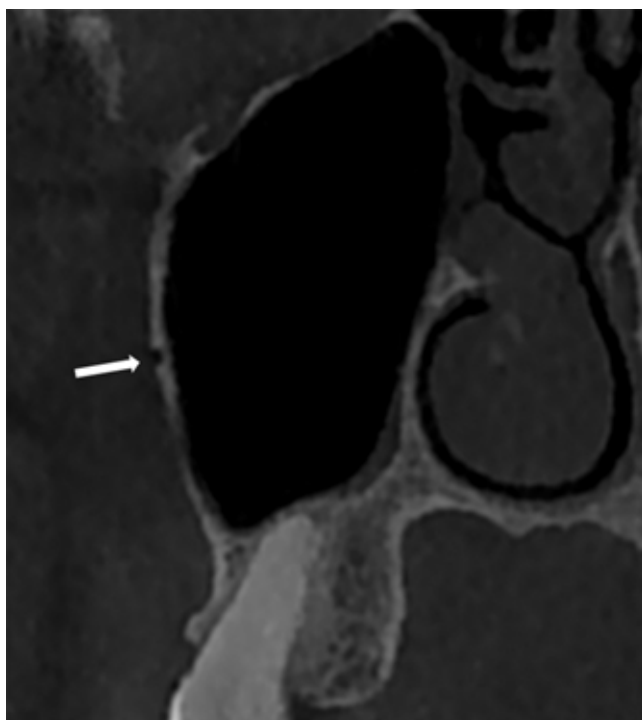
## Discussion

After tooth loss, alveolar bone resorption and maxillary sinus pneumatization decrease the amount and quality of bone in the posterior region of the maxilla. If an implant-supported prosthetic treatment is considered, the presence of adequate bone in this region is important for the success of the procedure [15]. Although sinus floor elevation with lateral approach is a common and successful method to obtain adequate bone for implant placement, there are several complications during and after the procedure. AAA damage is the second most common complication after the deterioration of the sinus membrane integrity during bone window preparation [6]. Therefore, the vessels supplying maxillary sinus have to be well studied to minimize complications that may occur during and after the sinus floor elevation. Damage to the AAA during the procedure may lead to hemorrhage and prolonged operation time, decreased vision in the surgical field, difficulty in membrane manipulation, membrane perforation after the procedure and bone necrosis [16]. Surgical planning using CBCT is critical to reduce the risk of AAA injury during the sinus floor elevation with lateral approach [17].

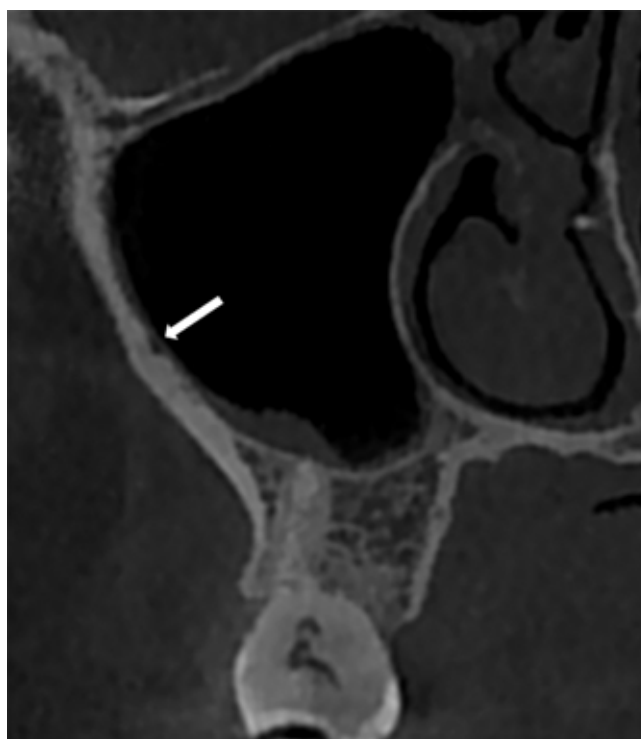
The blood supply of the bone graft placed after sinus floor elevation is partially achieved by the maxillary sinus mucosa and mainly by the PSAA. Many researchers have emphasized that the protection of vessels in this region is very important in terms of sufficient blood supply, bone healing and osseointegration of dental implants [18-21]. Gray et al. [19] emphasized the importance of blood supply in the region rather than the type of graft used, and reported that if there is a good blood supply in the region under the membrane, and if the vessels are not damaged during surgery, ossification could be achieved even with oxidized cellulose rather than bone grafts.

In our study, the prevalence of the detected artery significantly increased antero-posteriorly from the 1st premolar to the 2nd molar. Watanabe et al. [22] showed the prevalence of AAA at the regions of 1st premolar, 2nd premolar, 1st molar, and 2nd molar 28.9%, 58.6%, 48.2%, and 41.4%, respectively. Lee et al. [23] noted 1.3% for the 2nd premolar region, 16.7% for the 1st molar region and 34.8% for the 2nd molar region. In our study, the artery was most often detected in the 2nd molar region which is consistent with the reports of Lee et al. [23].

The diameter of the artery has been reported to reach up to 3 mm [16,21]. The increase of risk of bleeding during the surgical procedures applied to the region is directly proportional to the diameter of the vessel regardless of the technique used [16,18,21]. In the previous studies, the mean diameter of AAA was reported to be between 0.63 mm and 1.52 mm [17,24]. In our study, the mean diameter of AAA in the Turkish population sample was found to be 0.91 mm, ranging from 0.25 mm to



**Figure 1.** Coronal view of the maxillary sinus, showing the artery (arrow), which is on the outer cortex of the lateral sinus wall (superficial).



**Figure 3.** Coronal view of the maxillary sinus, showing the artery (arrow), which is below the Schneiderian membrane (intra-sinusal).



**Figure 2.** Coronal view of the maxillary sinus, showing the artery (arrow), which is inside the bone (intraosseous).

2.90 mm. This variability in the mean diameter of AAA may be attributed to racial differences in the study populations. Likewise in a Turkish population Ilguy et al. [3] reported the mean diameter of AAA as  $0.94 \pm 0.26$  mm. Also in a Turkish population Duruel et al. [20] reported AAA diameters in 1st premolar, 2nd premolar, 1st molar, and 2nd molar regions as 0.97, 0.88, 0.9, and 0.94 mm, respectively. Our findings were consistent with the previous studies of Ilguy et al. [3] and Duruel et al. [20]

in the aspect of mean diameter but additionally it has been detected that the diameter increased antero-posteriorly from the 1st premolar to the 1st molar in this study.

AAA could not be detected sometimes when the diameter is too small ( $<0.5$  mm) and runs inside the sinus or completely out of the bone. Therefore, both the anatomical information and radiological evaluation of AAA are important to avoid complications in sinus floor elevation with lateral approach [5,6]. The damage of the artery with a diameter larger than 1 mm may cause a surgical obstacle, which further increases to diameters over 2 mm [6,21]. In our study, 61.5% of the arteries were  $<1$  mm; 37.8% were 1–2 mm, and 0.8% were  $\geq 2$  mm. Moreover, all arteries with  $\geq 2$  mm diameter were located in the 2nd molar region. In our study, AAA diameter increased antero-posteriorly from the 1st premolar to the 1st molar. Although the mean AAA diameter was the largest in the 2nd molar region than the others, no significant difference was found in the mean diameter between the 1st molar and 2nd molar regions.

In the literature, several authors reported gender differences in the diameter of AAA, that is, males had a greater diameter than females [4,8,18], while Mardinger et al. [21] showed no such difference. In our study, the mean diameter of the AAA in males ( $1.01 \pm 0.38$  mm) was significantly greater than in females ( $0.86 \pm 0.28$  mm). This difference in the diameter of the AAA between genders can probably be attributed to the fact that males are generally physically larger than females in most dimensions.

The relationship of AAA with the lateral wall of the sinus affects the risk of hemorrhage. Intrasinusal type AAA, which is located between the sinus membrane and the internal aspect of the bony wall, makes the process of membrane elevation critical [25]. In many studies, intrasinusal type AAA has been reported

as the second most common type [3,18,25] and it was found to be 39.0% in our study. The intrasinus type was also the most common in the 1st molar region. The risk of hemorrhage is also present during incision when AAA is located on the outer surface of the sinus lateral wall [11]. The superficial type of AAA is rarely seen and in none of the previous studies has been over 8% [3,18,25]. In the present study, the superficial type AAA was found to be 3.3%. It was also observed that 95.24% of all superficial type of AAAs was in the 2nd molar region and no superficial type was observed in the 1st and 2nd premolar regions.

### Conclusion

In conclusion, the present study revealed a significant increase in the prevalence of the detected arteries antero-posteriorly from the 1st premolar to the 2nd molar. All the arteries with  $\geq 2$  mm diameter were detected in the 2nd molar region. The majority of superficial type AAA was also observed in the 2nd molar region. Considering this data, if sinus floor elevation by lateral approach is required before dental implant placement, the flap design with releasing vertical incision in the mesial instead of to the 2nd molar area may be helpful to avoid AAA injuries during the incision. The evaluation of the AAA in maxillary sinus on CBCT images before surgery could reduce the possibility of excess bleeding during surgery, especially in molar areas.

### Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

### Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

**Funding:** None

### Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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### How to cite this article:

Fahrettin Kalabalik, Hüseyin Akçay. Evaluation of the alveolar antral artery position in the lateral sinus wall using cone-beam computed tomography. *Ann Clin Anal Med* 2020;11(4):330-334